METHOD IN AN ELECTRIC NET DATA TRANSMISSION SYSTEM FOR KEEPING THE SIGNAL LEVEL CONSTANT IN A COUPLING FURNISHED WITH SUPPLY CABLE

The common problem by data transmission in low voltage net for example 12 VAC/DC, 24 VAC/DC, 48VAC/DC, 115 VAC, 230 VAC and 400VAC is the weakening of the transmission signal in the supply cable i.e. in the network connection cable, for instance only a fraction of signals sent by the transmitter gets to the network phase rail. The problem is most severe when the supply cable is long and when the rail impedance at used signal frequencies very low. Among other things, this problem can prevent commercial profiting of net data transmission systems.

The invention removes the problem in eliminating the impact of the weakening on coupling capacitor C_C and of supply cable L_W, $\underline{Z}_W$. Thus the standard-allowed maximum signal SFS-EN-50065-1:122 dBuV is produced in the network rail and in this respect data transmission in a low voltage net is made reliable even with low net impedance $\underline{Z}_{LOAD}$.

Even in most advanced solutions of present technique, where the output signal of the apparatus is constant, in other words independent of the net impedance, the coupling capacitor Cc and supply cable cause weakening of the transmission signal. The situation is especially bad, when the net impedance is very low.

Figure 1 shows the weakening of transmission signal by a 3 meter supply cable. Thereby the weakening is about 7 dB, but the length of supply cable being for instance 10 m the weakening is even 14 dB (1/5 voltage) when the load impedance of net impedance $Z_{\underline{LOAD}}$ is 1 ohm.

The block diagram of the invention is presented in figure 2. Block 10 is the source of operating voltage furnished with constant or adjustable output voltage U_S. U_S is the operating voltage of signal amplifier 20.

Input signal $\underline{U}_{IN}$ (e.g. under 95 kHz, 95-125 kHz, 125-140 kHz or 140-148,5 kHz) can be a sinus or a square signal to its amplitude e.g. 5 V_{PP}. The input signal is taken by adjustable

amplification or, after signal amplifier 20, furnished with level regulation $\underline{U}_{OUT}$ to low pass or band pass filter 40, where harmonic (crack) signals are filtered out from the basic frequency signal. Filtered signal $\underline{U}_{FL}$ is then taken to coupling unit 50 in the network and further to the low voltage net L-N e.g. with a 3 meter supply cable.

The network impedance between phase rail and zero rail, rail impedance, is described by signal frequencies with load impedance $\underline{Z}_{LOAD}$. The series impedance is described with impedance $\underline{Z}_{W}$. The supply cable length is $_{LW}$.

Dotted broken line A illustrates the traditional idea of the transmitting apparatus, which has an output connector O reference n r. 51: L-N. Dotted broken line B illustrates an expanded idea of the sending apparatus according to this invention. Then the supply cable is a fixed part of the apparatus and the output coupling of the apparatus, expanded as per this idea, is the supply cable ends l-n to be connected to the phase and the zero rail. The supply cable length must be of prior art as well as its electric and other properties.

The basic idea of this invention is that <u>a supply cable of certain length and type</u> L_W, $\underline{Z}_W$ is a fixed part of the transmission apparatus and between cable ends l – n, coupled to the network phase rail and zero rail, the rail voltage is kept constant by means of feedback coupling. The output coupling L – N of the transmitting apparatus is at the same time a phase and zero rail connection. In this way the transmission signal $\underline{U}_{LOAD}/\underline{Z}_{LOAD}$ amplitude U_{LOAD}, which must be put in between phase and zero rail, is constant.

The intern generator impedance of the signal generator, formed by transmitter and connecting cable, can in this way be formed almost to a rate of 0 ohm measured in the voltage rail or wall outlet connection.

The invention is not in contradiction for instance with standard SFS-EN 50065-1, since the signal voltage U_{LOAD} in voltage rail or in wall outlet does not under no circumstances exceed the allowed rate 122 dBuV. The same result could be reached also without the invention if the length of supply cable would be, for instance, only 10-20 cm. Generally, in practice it would, however, be impossible.

Operation alternative 1 BLOCKS 60 and 70

Steered before actual data transmission by micro processor μP included in block 70 the signal amplifier 20 sends a reference level signal of brief duration, e.g. 40 ms, in such a way that the signal amplifier always receives its constant control voltage U_{RC} (RC = REFERENCE CONTROL) from the sample/holding/steering block 70. The level of U_{RC} is such kind that from a load impedance $\underline{Z}_{LOAD}$ = 50 ohm a transmission signal $\underline{U}_{LOAD}$ in size of e.g 3,56 V_{PP} would be reached. U_{LC} is out of function.

During transmission the load impedance (network rail impedance) $\underline{Z}_{LOAD}$ is what it happens to be at that moment. Block 60 measures the transmission signal $\underline{U}a$ from block 20, $\underline{U}_B$ from block 40 or $\underline{U}_C$ from block 50 and $\underline{U}_D$ from block 50. The transmission signal voltage $\underline{Ua}, \underline{Ub}$ or $\underline{Uc}$ is the lower the lower $\underline{Z}_{LOAD}$ is. In block 50 of signal transformer T_C the primary current I_C is measured by measuring the signal voltage U_D R = 0,5 ohm exceeding the series resistance. $\underline{I}_C$ is the higher the lower the $\underline{Z}_{LOAD}$ is.

Alternatively instead of above Ic of signal current it is also possible to measure the secondary current $\underline{I}_{LOAD}$ of the signal transformer T_C, which current runs-through coupling capacitor C_C to supply cable and further to load impedance $\underline{Z}_{LOAD}$. The signal voltage U_D to be measured is proportional to signal current Ic or I_{LOAD}. If the $\underline{I}_{LOAD}$ is measured by measuring $\underline{U}_D$ and/or $\underline{U}_C$ the coupling capacitor T_C is measured from the secondary side before or after the coupling capacitor C_C, still a separate coupling unit is needed for coupling of signals $\underline{U}d$ and $\underline{U}c$ to block 60.

Alternatively signal voltage $\underline{U}d$ can instead of block 50 be measured from block 20 or 40. Signal voltage Ud gives information of signal current $\underline{I}_{LOAD}$ in transmission situation.

The phase angle Ø between $\underline{U}a, \underline{U}b, \underline{U}c$ and $\underline{I}c$ depends on the phase angle of $\underline{Z}_{LOAD}$, in other words in what extent the $\underline{Z}_{LOAD}$ is resistive, capacitive or inductive. Block 60 includes a phase difference detector and signal handling elements and a lot of screening. On basis of above data in block 60, for instance, following variables are calculated:

$$Z = Ua/Ic,\ Ub/Ic \text{ or } Uc/Ic \text{ ohm}$$

$$Z/\emptyset = \underline{Z}$$

$$\emptyset = (\underline{U}a,\ \underline{I}c \text{ or } \underline{U}b\ \underline{I}c \text{ or } \underline{U}c,\ \underline{I}c)$$

Impedance $\underline{Z}$ is a kind of a virtual impedance, on basis of which absolute value Z and on basis of phase angle Ø data of the $\underline{Z}_{LOAD}$ absolute value and phase angle is received

In block 60 direct voltages U_Z and $U_{\emptyset}$ proportional to measured impedance Z and phase angle Ø are formed and taken to block 70 to the microprocessor that by means of U_{LC} memory map transforms them into control voltage to steer the amplifications or levels of signal amplifier 20 into such state that into load impedance $\underline{Z}_{LOAD}$ a transmission signal 3,56 V_{PP} or 122 dBuV , constant to its level, is produced. U_{LC} remains in the holding circuit of block 70 till after about 1-4 seconds it gets removed by a new U_{CL} value determined by the next new reference measuring (LC = LEVEL CONTROL).

All in all, always, for instance for 40 ms, the apparatus sends a transmission signal according to certain reference level, for instance at intervals of 1-4 ms. During the mentioned 40 ms a virtual impedance $\underline{Z} = Z/\underline{\emptyset}$ proportional to the size and phase angle of load impedance $\underline{Z}_{LOAD}$ is determined, the variables U_Z and $U_{\emptyset}$ determined by which pick from the U_{LC} memory map an U_{LC} control voltage corresponding to them in order to regulate them to such a state that the U_{LOAD} of the transmission signal level is 3.56 V_{PP} with the load impedance in question.

Alternatively, for the above presented virtual impedance method ($Z\angle\emptyset$) the control voltage U_{LC} of signal amplifier 20 can be formed simply by means of transmission signals $\underline{U}a$, $\underline{U}b$ or $\underline{U}c$, and by means of $\underline{U}d$ amplitude monitoring.

The transmitting apparatus, reckoned from signal amplifier 20 and advancing through the low pass and/or band pass filter 40 and the network of block 50 to the supply cable and finally further to the load impedance $\underline{Z}_{LOAD}$, includes capacitors, resistances, minithrottles, a transformer and other inductances and capacitors. Accordingly, by means of different load impedance $\underline{Z}_{LOAD}$ values it is possible to measure from different locations in the apparatus transmission signals of different size (Ua,Ub,Uc,Ud) as to their amplitude. For instance, on basis of amplitude combinations of two transmission signals, as Ub and Ud, the size and

nature of load impedance $\underline{Z_{LOAD}}$ can be concluded. It is the question of an <u>amplitude method</u> as an alternative to the virtual impedance method.

Figure 2: Block diagram of the invention and figure 6: U_{LC} memory map = U_{LC} (Z, Ø). With control voltage U_{LC} it is possible in addition to block 20 or alternatively to control block 40, 50 and/or block 10. The same also concerns control voltage U_{RC}.

<u>Operation alternative 2 BLOCKS (80 and 90)</u>

Feedback coupling is taken from the phase and zero rail (rail voltage) $l_{LOAD} - n_{LOAD}$ or for example from wall outlet through coupling unit 80 to the ALC/ALG block 90, where control signal U_{ALC} or U_{AGC} or U_{ACC} is formed to control the level of signal amplifier 20 or the amplification formed to such a state that the level U_{LOAD} of the transmission signal is constant, in other words independent of the load impedance $\underline{Z_{LOAD}}$.

ALC = Automatic Level Control

AGC = Automatic Gain Control

ACC = Automatic Cutting Control

Control voltage U_{ALC}, U_{AGC} and/or U_{ACC} can in addition to block 20 or alternatively control block 40, 50 and/or block 10. The same is in question also with control voltage U_{RC}.

The net work connecting unit, input unit 50 and the output unit 80 include in case of galvanic separation a coupling transformer T_C and T_{CC} and a coupling capacitor C_C and C_{CC} and possibly also other components. There is in a so called direct coupling no galvanic separation from the network and the coupling units 50 and 80 can in their simplicity include only a coupling capacitor C_C and C_{CC}.

<u>A practical application. Figure 3</u>

Figure 3 shows a practical application of the invention. The operating principle is already described above. In connection with U_{LC} memory map, figure 6, it can be stated that it

presents the control voltage values U_{LC} of the signal amplifier corresponding to 304 different load impedance $\underline{Z}_{LOAD}$ values, by means of with it is then possible to bring about to the load impedance in question a constant signal transmission voltage U_{LOAD} 3,56 V_{PP} or 122 dBuV. In addition to the $\underline{Z}_{LOAD}$ of impedances it presents the $\underline{Z}= Z\angle Ø$ values Z and Ø of the measured virtual impedance, as addresses of the storage location, and the U_{LC} value as content of said storage location. The virtual impedance $\underline{Z}$ is, in addition to block 50, also affected by block 20 and 40 preceding it and by the supply cable. Accordingly, the virtual impedance does not give any good linear picture of load impedance $\underline{Z}_{LOAD}$ especially in so far as the phase angle Ø is concerned. This is due to the fact that from signal amplifier 20 to load impedance $\underline{Z}_{LOAD}$ there are throttles, a transformer, capacitors and a supply cable, by the interaction of which there are phase distortions as well as by different resonance effects. One brilliant idea of the invention is that its above mentioned circumstances are of no importance at all, since it is enough that the virtual impedance in some way depends only on the $\underline{Z}_{LOAD}$ and the supply cable and only in some way differing virtual impedance values Z and Ø are produced and by this means U_{LC} memory map addresses Z and Ø. Then into appropriate storage location such a control voltage value U_{LC} of the signal amplifier is stored that by means of it a proper output voltage U_{OUT} of signal amplifier and a constant transmission signal (rail signal) $\underline{U}_{LOAD}$ to the appropriate load impedance $\underline{Z}_{LOAD}$ is produced.

The invention functions by dotlike frequencies or by a certain frequency band. An U_{LC} memory map is always needed for frequencies or frequency bands far enough from one another and for different supply cables. If the virtual impedance is not exactly the same as some storage location address, the closest or a more proper address is chosen.

In the U_{LC} memory map there can be more or even less than 304 storage locations. In practice a whole swarm of memory maps may be needed. If a sufficient amount of supply cables of different length and type are used and with frequencies or frequency bands far enough from one another for each case an own U_{LC} memory map is needed. Instead of the 3 m length the

supply cable can be even longer, but then the it may be necessary to increase the operating voltage of signal amplifier 20.

The value tolerances of the transmitter components must be small enough precision components or then by each entire transmitter unit an U_{LC} memory map is programmed in a special programming location individually by serial production. This applies to this and the next practical application.

Another practical application of the invention. Figure 4

Instead of the virtual impedance method the amplitude method can be used in order to generate a control voltage U_{CL}. In the amplitude method it is possible to determine, on basis of two, for instance Ub and Ud signal voltage amplitudes, from the U_{LC} memory map U_{LC}= U_{LC} (Ub and Ud) a control voltage U_{LC} corresponding to load impedance $\underline{Z}_{LOAD}$ can be determined, which regulates the signal amplifier outlet voltage U_{OUT} as to its amplitude to such state that rail signal $\underline{U}_{LOAD}/\underline{Z}_{LOAD}$ is constant as to its level, in other words 3,5 V_{pp} or 122 dBu V. Quite clear differences have been measured for Ub and Ud, when $\underline{Z}_{LOAD}$ = 1 – 50 ohm and $Ø_{LOAD}$ = 0- ±90°: Ubmax-Ubmin = 6 V_{pp} and Udmax -Udmin = 310 mV_{pp}/0,5 ohm. The Ub and Ud amplitude can be measured by A/D transformer (10 and 8 bits) during transmission of an ohm signal 3,56 V_{pp} of reference level, for instance 40 ms/ 1 - 4 seconds. The bit figure 10 + 8 received from A/D transformer, corresponding to Ub and Ud, can function directly as address of memory map, from the storage location indicated by it, a control voltage, proper for the situation, is reached for U_{LC} signal amplifier 20 by means of the holding circuit in block 70. From U_{LC} memory map the closest or more proper address is chosen if the measured address is not exactly the same. Instead of the A/D transformer comparator degrees can be used to measure the Ub and Ud levels of transmission signals by steps.

The U_{LC} memory map presented in figure 6 is suited also for this practical application and if the address co-ordinates Z and Ø of the storage locations are correspondingly transformed into Ub and Ud. $U_{LC} = U_{LC}$ (Ub,Ud).

A third practical application of the invention. Figure 5.

Figure 7 shows of this practical application transmission signal level U_{LOAD} (1) with feedback coupling and without feedback coupling U_{LOAD} (2) as function of load impedance (rail impedance) Z_{LOAD}. Figure 7 shows the signal levels of figure 5 practical application. The transmission signal of the real apparatus is $U_W + U_{LOAD}$ in net connector (51) with feedback coupling.

Previously known is that the longer the supply cable L_W,Z_W of the transmitter of a data transmission system in a low tension net, and the lower the impedance by signal frequencies in the supply cable other end (load impedance or rail impedance) Z_{LOAD}, the lower the voltage level U_{LOAD} of the transmission signal.

However, previously no effective means are known how to eliminate the strong weakening of signal caused by above mentioned circumstances. The problem does not vanish in that the transmitter maintains to keep the signal level constant in its output connector.

Operation alternative 1:

In transmission situation signal (U_{OUT} block 20) of certain level reference is sent repeatedly but briefly and during that time one or more transmission signals Ua,b,c...Un are measured from different locations of the transmitting apparatus (apparatus + supply cable), by means of which signals amplitudes, phase shift keying, proportions, multiplies, sums and other features of the output signal is regulated the blocks 20, 40, 10 and/or 50 in the transmitter directly or by means of control signals (block 60 and 70) to such a state that the amplitude $\underline{U}_{LOAD}$ of the rail signal U_{LOAD} is constant, in other words independent of load impedance $\underline{Z}_{LOAD}$ till the transmission of the next reference level signal. Signals Ua-Un, U_Z, $U_\emptyset$, U_{RC}, U_{LC}, U_{ALC}, U_{ACC} and U_{AGC} can instead of the voltage signal be current signals, frequency signals, code signals, electric field signals, magnet field signals, optical signals, electromagnetic signals and/or signals of other possible types.

Operation alternative 2:

In transmission situation the feedback signal is taken directly from the rail impedance $\underline{Z}_{LOAD}$

poles or near the poles (usually from the phase and zero rails). The feedback signal is brought to output signal 80 by separate conductors further to ALC/AGC/ACC block 90, where control voltage U_{ALC}, U_{AGC} and/or U_{ACC} to be produced, is taken to control the output or voltage signal of block 20, 40, 10 and/or 50 to such state that the amplitude $\underline{U}_{LOAD}$ of rail signal U_{LOAD} is constant or almost constant.